CLAIMS

1. A powertrain, comprising:

a primary power generating system for generating a primary drive torque, the primary power system having a hydrogen-fuelled internal combustion engine operating with a lean hydrogen gas fuel mixture, the internal combustion engine having at least one air charge boosting device for increasing the primary drive torque at a range of operating speeds of the powertrain; and

a secondary power generating system having at least one electric torque generating device for generating a secondary drive torque, the secondary power generating system being constructed and arranged such that the secondary drive torque complements the boosted primary drive torque over at least a low operating speed range of the powertrain.

2. A powertrain according to claim 1, wherein the primary power generating system comprises at least one intercooling device.

3. A powertrain according to claim 1, wherein the primary power generating system comprises a dual stage intercooler.

4. A powertrain according to claim 1, wherein the primary power generating system comprises a front end accessory assembly optimised for reducing noise, vibration and harshness (NVH) associated with the powertrain.

5. A powertrain according to claim 1, wherein the primary power generating system is shielded with a sound absorbing barrier to reduce NVH emanating from the air charging device.

6. A powertrain according to claim 1, wherein the secondary power generating system comprises an electrical motor/generator.

7. A powertrain according to claim 1, further comprising a disconnect clutch disposed between the primary generating power system and the secondary power generating system for engaging and disengaging the primary power generating system from the secondary power generating system and for transferring the boosted primary driver torque through the secondary power generating system.

8. A powertrain according to claim 7, wherein the disconnect clutch comprises a wet clutch assembly.

9. A powertrain according to claim 7, wherein the disconnect clutch comprises a dry clutch assembly.

10. A powertrain according to claim 1, further comprising a power transmission system coupled to the output of the secondary power generating system for receiving a combination of the boosted primary drive torque and the secondary drive torque, the combination of the boosted primary drive torque and the secondary drive torque having an enhanced torque characteristic over at least the low operating speed range of the powertrain.

11. A powertrain according to claim 10, wherein the power transmission system is a manual transmission.

12. A powertrain according to claim 10, wherein the power transmission system is an automatic transmission.

13. A powertrain according to claim 10, wherein the power transmission system is a continuously variable transmission.

14. A powertrain according to claim 1, further comprising:

a disconnect clutch disposed between the primary generating power system and the secondary power generating system for engaging and disengaging the primary power generating system from the secondary power generating system and for transferring the boosted primary driver torque through the secondary power generating system; and

a power transmission system coupled to the output of the secondary power generating system for receiving a combination of the boosted primary drive torque and the secondary drive torque, the combination of the boosted primary drive torque and the secondary drive torque having an enhanced torque characteristic over at least the low operating speed range of the powertrain, the secondary power generating system, the disconnect clutch and the power transmission system being packaged as a modular hybrid transmission system.

15. A vehicle, comprising:

a hydrogen storage system for storing hydrogen fuel;

a hydrogen-fuelled internal combustion engine coupled to the hydrogen storage system, the internal combustion engine operating with a lean hydrogen gas fuel mixture, the hydrogen-fuelled internal combustion having at least one air charge boosting device for increasing the primary drive torque primarily over a wide operating speed range;

an electrical storage device; and

an electric motor/generator coupled to the electrical energy storage device for generating a secondary drive torque for the vehicle and for recovering electrical energy for storage in the electrical storage device, the electric motor/generator being constructed and arranged such that the secondary drive torque complements the boosted primary drive torque over at least a low operating speed range.

16. A vehicle according to claim 15, wherein the hydrogen storage system comprises a compressed hydrogen gas storage system.

17. A vehicle according to claim 15, wherein the hydrogen storage system comprises a liquid storage system.

18. A vehicle according to claim 15, wherein the hydrogen storage system comprises a solid metal storage system.

19. A vehicle according to claim 15, wherein the hydrogen storage system is arranged in a rear or middle portion of the vehicle.

20. A vehicle according to claim 15, wherein the electrical storage device comprises a battery.

21. A vehicle according to claim 15, wherein the electrical storage device comprises an ultra capacitor.

22. A vehicle according to claim 15, wherein the electrical storage device is arranged in a rear or middle portion of the vehicle.

23. A vehicle according to claim 15, further comprising:

a disconnect clutch disposed between the internal combustion engine and the electric motor/generator for engaging and disengaging the internal combustion engine from the electric motor/generator and for transferring the boosted primary drive torque through the electric motor/generator; and

a power transmission system coupled to the output of the electric motor/generator for receiving a combination of the boosted primary drive torque and the secondary drive torque, the combination of the boosted primary drive torque

and the secondary drive torque having an enhanced torque characteristic over at least the low operating speed range.

24. A vehicle according to claim 23, wherein the internal combustion engine, the electric/motor generator, the disconnect clutch and the power transmission system are arranged in a forward portion of the vehicle.

25. A vehicle according to claim 23, wherein the electric/motor generator, the disconnect clutch and the power transmission system are packaged as a modular hybrid transmission system.

26. A vehicle according to claim 25, wherein the internal combustion engine and the modular hybrid transmission system are arranged in a forward portion of the vehicle.

27. A vehicle according to claim 15, further comprising at least one sound absorbing barrier in the vicinity of the engine and the modular hybrid transmission system.

28. A vehicle according to claim 15, further comprising a hydrogen ventilation system.

29. A method of operating a hybrid vehicle having a hydrogen-fuelled internal combustion engine, comprising:

generating a primary drive torque for the vehicle using a lean hydrogen gas fuel mixture;

increasing the primary drive torque primarily over a high operating speed range;

generating a secondary drive torque such that the secondary drive torque complements the boosted primary drive torque over at least a low operating speed range;

selectively transferring a combination of the boosted primary driver torque and the secondary drive torque, the

combination of the boosted primary drive torque and the secondary drive torque having an enhanced torque characteristic over at least the low operating speed range.

30. A method for changing the fuel delivery rate for a hydrogen fuelled internal combustion engine having pulsed fuel injectors including, for each cylinder, a low flow fuel injector and a high flow fuel injector, comprising the steps of:

increasing the fuel delivery rate by increasing the pulse width of the low flow injector until the flow rate has reach an overlap value;

operating the high flow injector at a rate approaching the overlap value; and

simultaneously decreasing the pulse width of the low flow injector such that the total flow from the high and low flow injectors is equal to the maximum flow from the low flow injector.

31. A method according to claim 30, further comprising the steps of:

decreasing the fuel rate from a higher fuelling rate by decreasing the pulse width of the high flow rate injector until the flow rate has reached the overlap value; and

simultaneously operating said low flow injector at the overlap value, while turning said high flow injector off.

32. A method for sensing and responding to a backfire arising in the intake system of a hydrogen fuelled reciprocating internal combustion engine, comprising the steps of:

sensing a backfire by sensing the temperature within the intake system; and

shutting off the hydrogen fuel to the engine when a backfire is sensed.

33. A method according to claim 32, further comprising the step of increasing the output torque of an electric drive system associated with the engine in the event the hydrogen fuel is shut off.

34. A method according to claim 32, further comprising the step of sensing a backfire by sensing the pressure within the engine's intake system.

35. A method according to claim 32, further comprising the step of resuming fuelling of the engine with hydrogen once a backfire event has ceased.